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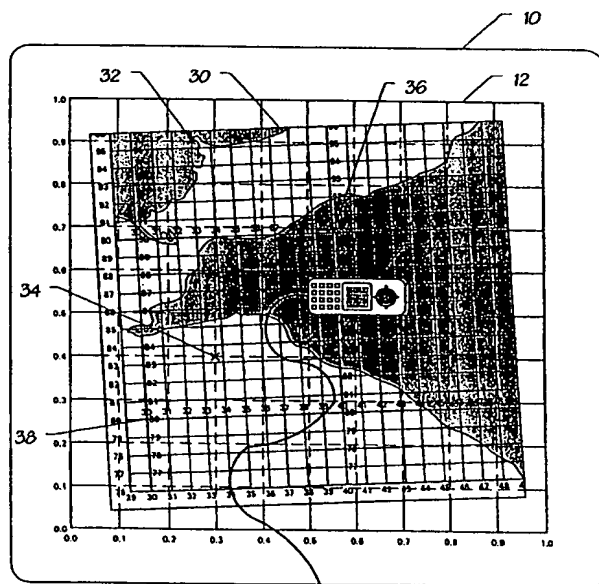
INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : G01C 21/22, G09B 29/10		A1	(11) International Publication Number: WO 99/56082 (43) International Publication Date: 4 November 1999 (04.11.99)
(21) International Application Number: PCT/GB99/01275 (22) International Filing Date: 23 April 1999 (23.04.99) (30) Priority Data: 9808692.9 23 April 1998 (23.04.98) GB (71) Applicant (for all designated States except US): YEOMAN GROUP PLC [GB/GB], Chichester House, 278-282 High Holborn, London WC1V 7HA (GB). (72) Inventor; and (75) Inventor/Applicant (for US only): AGNEW, Hugh, John [GB/GB], Yeoman Marine Limited, The Shipyard, Bath Road, Lynnhington, Hampshire SO41 9YL (GB). (74) Agents: BERESFORD, Keith, Denis, Lewis et al.; Beresford & Co., 2-5 Warwick Court, High Holborn, London WC1R 5DJ (GB).		(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  Published With international search report.	

(54) Title: REFERENCING MAPS WITH RESPECT TO DIGITISING APPARATUSES

(57) Abstract

A digitising apparatus is disclosed which comprises: a digitising surface (12) having a digitiser coordinate system and on which a map (30) can be laid; a cursor (14) by which a user can indicate positions on the map on the digitiser surface; means (10, 14) for detecting the digitiser coordinates of the position indicated by the user with the indicating means; and a processor (18). In order to reference the map with respect to the digitising surface when used with a map which is marked with a set of grid points of a map coordinate system, the processor is operable in a referencing mode: to receive from the detecting means the digitiser coordinates of a position (36) which is indicated by the user with the cursor and which is at an arbitrary one of the grid points; to determine [from the detected digitiser coordinates of the indicated position, grid spacing information and parameters of an initial (not necessarily particularly accurate) mapping] the map coordinates of that one of the grid points which is at the indicated position; and to determine parameters of a revised mapping which takes account of the correlation between the detected digitiser coordinates of the indicated position and the determined map coordinates of the indicated position.



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## TITLE

Referencing Maps with respect to Digitising Apparatuses

DESCRIPTION

This invention relates to a method of referencing a map with respect to a digitising apparatus, and also to a digitising apparatus having a digitising surface on which a map can be laid.

Examples of such methods and apparatus are known from patent documents  
5 EP-A-0268628 and WO-A-95/01551. In both cases, the digitising apparatus has a digitising surface with its own coordinate system. A map can be laid on the digitising surface, and the map, of course, has its own coordinate system. The apparatus also includes some means, such as a cursor or puck, by which a user can indicate a position on the map on the digitising surface, and for detecting the digitiser  
10 coordinates of the indicated position. In order to provide many of the features described in the above two documents, an accurate mapping is required between the coordinate systems of the digitising surface and the map, and it is therefore necessary to reference the map accurately with respect to the digitising surface.

EP-A-0268628 describes a referencing method in which the cursor is placed at  
15 three arbitrary positions of known latitude and longitude, and at each position the user enters the latitude and longitude values, and the apparatus detects the position of the cursor on the digitising surface. A processor then sets up a mathematical mapping between the two coordinate systems. A similar referencing method is briefly described in WO-A-95/01551.

20

A problem with the above methods is that they require the cursor to be

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positioned accurately at three places on the map, and also require three latitude and longitude pairs of values to be entered by the user.

In a modification to the above method also described in EP-A-0268628, which avoids the need for the user entering the latitude and longitude values, the three  
5 positions are not arbitrary, but are marked on the map, and the latitude and longitude values for those three positions can be read by the apparatus from a bar code provided on the map. However, this modification requires all three referencing positions to be over the digitising surface. In some cases, maps are used which are far larger than the digitising surface so that they overhang the edges of the digitising surface or placed  
10 on it in a folded condition, and this modification cannot then be used, or at least not for all areas of the map.

In accordance with a first aspect of the present invention, there is provided a method of referencing a map which is marked with a set of grid points. The method comprising the steps of: determining parameters of an initial mapping between the  
15 map and digitiser coordinate systems; storing or receiving information from which the spacing between the grid points can be determined; receiving an indication from the user of a position which is at an arbitrary one of the grid points; determining the digitiser coordinates of the indicated position; determining (from the determined digitiser coordinates of the indicated position, the grid spacing information and the  
20 initial mapping parameters) the map coordinates of that one of the grid points which is at the indicated position; and determining parameters of a revised mapping which takes account of the correlation between the determined digitiser coordinates and map coordinates of the indicated position.

With this method, given the initial approximate mapping and the grid spacing  
25 information, the method can be thought of as making a calculated guess at the map coordinates of the arbitrary grid point indicated by the user, without the user needing to enter those map coordinates, and then improving the mapping accordingly.

In one simple example of the method of the first aspect of the invention, the revised mapping represents solely a translation of the initial mapping such that the

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determined digitiser coordinates and map coordinates of the indicated position are mapped onto each other by the revised mapping. In other words the revised mapping is merely a repositioning of the initial mapping.

In an improved example of the method of the first aspect of the invention, the method preferably further including the steps of: receiving an indication from the user of a second position which is at a second arbitrary one of the grid points; determining the digitiser coordinates of the indicated second position; and determining (from the determined digitiser coordinates of the indicated second position, the grid spacing information and the initial mapping parameters) the map coordinates of that one of the grid points which is at the indicated second position; the revised mapping parameters also taking account of the correlation between the determined digitiser coordinates and map coordinates of the indicated second position. In this case, the revised mapping may represent a translation, rotation and/or scaling of the initial mapping, and it may be such that the digitiser coordinates and map coordinates of the indicated first-mentioned position are mapped onto each other, and the digitiser coordinates and map coordinates of the indicated second position are mapped onto each other, by the revised mapping.

This example of the method may further include the steps of: receiving an indication from the user of a third position which is at a third arbitrary one of the grid points; determining the digitiser coordinates of the indicated third position; and determining (from the determined digitiser coordinates of the indicated third position, the grid spacing information and the initial mapping parameters) the map coordinates of that one of the grid points which is at the indicated third position; the revised mapping parameters also taking account of the correlation between the determined digitiser coordinates and map coordinates of the indicated third position. (These steps may also be repeated.) In this case, mappings which are more complex than merely scaling, translation and rotation may be employed.

Alternatively, the method may further include the steps of: receiving an indication from the user of a third position which is at a third arbitrary one of the grid

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points; determining the digitiser coordinates of the indicated third position;  
determining (from the determined digitiser coordinates of the indicated third position,  
the grid spacing information and the initial or revised mapping parameters) the map  
coordinates of that one of the grid points which is at the indicated third position; and  
5 determining parameters of a further revised mapping which takes account of the  
correlations between the determined digitiser coordinates and map coordinates of at  
least the indicated second and third positions. (Again, these steps may also be  
repeated.) Accordingly, the mapping may be updated (which might be necessary if the  
map has been slightly jogged on the digitiser), or if, for example, the user is  
10 particularly interested in one portion of the map, they can reference a grid point in  
that portion of the map so as to improve the mapping in that portion.

The initial mapping may be obtained in any convenient way. With one  
particularly convenient way, the step of determining the initial mapping parameters  
may include the steps of: receiving an indication from the user of the current position  
15 of the user; determining the digitiser coordinates of the indicated current position;  
receiving an indication of the map coordinates of the current position of the user;  
receiving an indication of the scale of the map; and determining the initial mapping  
parameters from the map scale and the determined digitiser coordinates and received  
map coordinates of the current position of the user. The step of determining the initial  
20 mapping parameters may also include the step of receiving and taking into account an  
indication (which need not be particularly accurate) from the user of the relative  
orientation of the map and digitiser coordinate systems. The map coordinates of the  
current position may conveniently be obtained from a positioning system, such as  
GPS.

25 In accordance with a second aspect of the present invention, there is provided  
a digitising apparatus which is adapted to perform the method of the first aspect of the  
invention.

In accordance with a third aspect of the present invention, there is provided a  
digitising apparatus, comprising: a digitising surface having a digitiser coordinate

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system and on which a map can be laid which is marked with a set of grid points of a map coordinate system; means by which a user can indicate positions on the map on the digitiser surface; means for detecting the digitiser coordinates of the position indicated by the user with the indicating means; first storing or receiving means for storing parameters of an initial mapping between the map and digitiser coordinate systems; second storing or receiving means for storing or receiving information from which the spacing between the grid points can be determined; and processing means operable in a referencing mode to: receive from the detecting means the digitiser coordinates of a position which is indicated by the user with the indicating means and which is at an arbitrary one of the grid points; determine, from the detected digitiser coordinates of the indicated position, the grid spacing information and the initial mapping parameters, the map coordinates of that one of the grid points which is at the indicated position; and determine parameters of a revised mapping which takes account of the correlation between the detected digitiser coordinates of the indicated position and the determined map coordinates of the indicated position.

A specific embodiment of the present invention will now be described, purely by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic illustration of a digitising apparatus; and

Figure 2 is similar to figure 1, but with a folded map placed on the apparatus.

#### Apparatus

Referring to figure 1, the digitising apparatus comprises, in a known manner, a digitising tablet 10 having an active area 12, a cursor, puck or mouse 14, a GPS receiver 16 and a processor 18. In figure 1, the active area 12 of the digitising tablet 10 is shown as having an (x, y) coordinate system ranging from (x, y)=(0, 0) to (x, y)=(1, 1). In a known fashion, the processor 18 is able to determine the (x, y) coordinates of the position of a datum point of the cursor 14 on the active area 12 of the digitising tablet 10. Also, in a known fashion, the processor 18 is able to

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determine the position of the GPS receiver 16 in a particular coordinate system such as latitude and longitude, or the Ordnance Survey of Great Britain (OSGB) grid. In the remainder of this specific description, it will be assumed that the GPS receiver 16 supplies OSGB coordinates  $(u, v)$  with a one metre resolution. Also in a known of manner, the cursor 14 has a keypad 22, a liquid crystal display 24, a transparent window 26, and a number of indicators 28 which can indicate to the user a required direction of movement of the cursor 14. For a further description of many of the functions of the digitising apparatus, reference is directed to patent document EP-A-0268628.

#### 10      Example Map

Referring now to figure 2, this shows part of a map 30, which is Sheet 196 of the OSGB 1:50000 Landranger series of maps, laid somewhat crookedly on the active area 12 of the digitising tablet 10. The map 30 has been folded into quarters so that only the southwest quarter is visible, covering the area  $(u, v) = (429000, 076000)$  to  $(u, v) = (449000, 096000)$ . A cross 32 is shown on the map 30, marking the position of The Shipyard, Bath Road, Lyminster, Hampshire, United Kingdom, at grid reference (432990, 095470). In the following example, it is assumed that the user (and therefore the GPS receiver 16) are currently at the position  $(u_c, v_c)$  of the cross 32, that is  $(u_c, v_c) = (432990, 095470)$ .

#### 20      Referencing the Map to the Digitiser

The processor 18 is programmed to perform the example of the new referencing method as follows:

A.      In response to the user pressing a key or combination of keys on the keypad 22 denoting that apparatus is to be set up for a new map, the processor 18 causes a message such as "Enter map scale" to be displayed on the display 24. Using the keypad 22, the user enters the nominal scale, which in this example is 50000, and this is stored as  $s_m = 50000$ . The apparatus is preprogrammed with the scale of the digitiser tablet 10 coordinate system, which in this example is  $s_d = 1/0.48$  units/metre



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(i.e. the size of the active area 12 of the digitiser tablet is 480 mm x 480 mm). Then, the processor 18 causes a message such as "Enter grid intersection spacing" to be displayed on the display 24. Using the keypad 22, the user enters the spacing between the primary grid lines on the map, which in this example is 10000, and this is stored  
5 as  $g = 10000$ .

B. In response to the user pressing a key or combination of keys on the keypad 22 denoting that referencing is to be performed, the processor 18 causes a message such as "place cursor on current position and press enter key" to be displayed on a display 24.

10 C. Once the user has placed the datum point 20 of the cursor 14 on the position of the cross 32 and in response to the user pressing the enter key, the processor 18 reads the current grid reference  $(u_c, v_c) = (432990, 095470)$  from the GPS receiver 16 and also the current cursor position, which in the example is  $(x_c, y_c) = (0.2508, 0.9033)$ , from the digitising tablet 10.

15 D. The processor 18 then causes a message such as "place cursor on position to North (0), West (1), South (2) or East (3) of current position, and press 0,1,2 or 3". This placing of the cursor does not need to be very accurate. Suppose that, in the example, the user places the datum point 20 of the cursor 14 on the position of the cross 34 and then presses the "2" key.

20 E. In response to the pressing of the key, the processor 18 notes the value  $d$  of the key and reads the cursor position  $(x_d, y_d)$ ; thus, in the example,  $d = 2$  and  $(x_d, y_d) = (0.3000, 0.4000)$ .

F. The processor 18 then causes a message such as "place cursor on first main grid intersection and press enter key". Suppose that, in the example, the user  
25 places the datum point 20 of the cursor 14 at the grid intersection  $(440000, 090000)$  (figure 2 reference 36) and presses the enter key.

G. In response to the pressing of the enter key, the processor 18 reads the cursor position  $(x_1, y_1)$ , which in the example is  $(x_1, y_1) = (0.5533, 0.6900)$ .

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H. The processor 18 then causes a message such as "place cursor on second main grid intersection and press enter key". Suppose that, in the example, the user places the datum point 20 of the cursor 14 at the grid intersection (430000, 080000) (figure 2 reference 38) and presses the enter key.

5 I. In response to the pressing of the enter key, the processor 18 reads the cursor position  $(x_2, y_2)$ , which in the example is  $(x_2, y_2) = (0.1567, 0.2542)$ .

J. The processor 18 then calculates the approximate angle  $\theta$  anticlockwise of the northings (v) direction of the map from the y axis of the digitising tablet 10. It will be appreciated that if  $d = 0$ , or  $d = 2$ , then  $\theta = \tan^{-1}[(x_c - x_d)/(y_d - y_c)]$ , and if  
 10  $d = 1$ , or  $d = 3$ , then  $\theta = \tan^{-1}[(y_d - y_c)/(x_d - x_c)]$ . Thus, in the example,  $\theta = 5.583^\circ$ .

K. The processor 18 then calculates the approximate grid references  $(u_1, v_1)$  and  $(u_2, v_2)$  of the first main grid intersection from:

$$\begin{aligned} u_1 &= u_c + (s_m/s_d)\{(x_1 - x_c).\cos\theta + (y_1 - y_c).\sin\theta\} \\ v_1 &= v_c + (s_m/s_d)\{(y_1 - y_c).\cos\theta - (x_1 - x_c).\sin\theta\} \\ 15 \quad u_2 &= u_c + (s_m/s_d)\{(x_2 - x_c).\cos\theta + (y_2 - y_c).\sin\theta\} \\ v_2 &= v_c + (s_m/s_d)\{(y_2 - y_c).\cos\theta - (x_2 - x_c).\sin\theta\} \end{aligned}$$

Thus, in the example:

$$\begin{aligned} (u_1, v_1) &= (439717, 089668) \\ (u_2, v_2) &= (429226, 080184) \end{aligned}$$

20 L. The processor 18 then rounds the grid references  $(u_1, v_1)$  and  $(u_2, v_2)$  to the nearest grid spacing  $g = 10000$  to determine the exact grid intersections  $(U_1, V_1)$  and  $(U_2, V_2)$ . Thus, in the example:

$$\begin{aligned} (U_1, V_1) &= (440000, 090000) \\ (U_2, V_2) &= (430000, 080000) \end{aligned}$$

25 M. The processor 18 now knows the map coordinates  $(U_1, V_1)$ ,  $(U_2, V_2)$  and the digitiser coordinates  $(x_1, y_1)$ ,  $(x_2, y_2)$  of the first and second main grid intersections, respectively, and can therefore set up a mapping for mapping each of the coordinate systems onto the other.

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Setting up the Mapping - First Method

The setting up of the mapping can be done in a number of ways. For example, it may be assumed that the coordinates  $(U_1, V_1)$ ,  $(U_2, V_2)$ ,  $(x_1, y_1)$ ,  $(x_2, y_2)$  are entirely correct and that the nominal scale of the map may be incorrect, for example because of stretching, shrinkage or wrinkling of the paper, or merely because of initial inaccuracies in the map. In this case, a corrected angle  $\Theta$  corresponding to the approximate angle  $\theta$  mentioned above is calculated by the processor 18 from:

$$\tan\Theta = \{[(U_1-U_2) \cdot (y_1-y_2)] - [(V_1-V_2) \cdot (x_1-x_2)]\} / \{[(U_1-U_2) \cdot (x_1-x_2)] + [(V_1-V_2) \cdot (y_1-y_2)]\}$$

where  $\Theta \approx \theta$ . In the example,  $\tan\Theta = 0.047093$ , and therefore  $\Theta = 2.696^\circ$ .

- 10 Furthermore, the corrected scale  $S_m$  of the map is calculated by the processor 18 from:

$$S_m = s_d \cdot \{[(U_1-U_2)^2 + (V_1-V_2)^2] / [(x_1-x_2)^2 + (y_1-y_2)^2]\}^{1/2}$$

In the example, the corrected scale  $S_m$  is calculated as 50001, as compared with the nominal scale  $s_m$  of 50000. Additionally, the map coordinates  $(U_0, V_0)$  corresponding to the origin  $(x, y) = (0, 0)$  of the active area 12 of the digitiser tablet 10 are calculated by the processor 18 from :

$$U_0 = U_1 - \{[x_1 \cdot \cos\Theta + y_1 \cdot \sin\Theta] \cdot S_m / s_d\}$$

$$V_0 = V_1 - \{[y_1 \cdot \cos\Theta - x_1 \cdot \sin\Theta] \cdot S_m / s_d\}$$

In the example:

20  $(U_0, V_0) = (425956, 074083)$

Now that the values of  $(U_0, V_0)$ ,  $S_m$ ,  $s_d$  and  $\Theta$  have been determined by the processor 18, the mapping from a general digitiser coordinate pair  $(x, y)$  to a general map coordinate pair  $(u, v)$  is given by:

$$u = U_0 + \{[x \cdot \cos\Theta + y \cdot \sin\Theta] \cdot S_m / s_d\}$$

25  $v = V_0 + \{[y \cdot \cos\Theta - x \cdot \sin\Theta] \cdot S_m / s_d\}$

and the inverse mapping from the general map coordinate pair  $(u, v)$  to the general digitiser coordinate pair  $(x, y)$  is given by:

$$x = \{(u-U_0) \cdot \cos\Theta - (v-V_0) \cdot \sin\Theta\} \cdot s_d / S_m$$

$$y = \{(v-V_0) \cdot \cos\Theta + (u-U_0) \cdot \sin\Theta\} \cdot s_d / S_m$$

- 30 With the specific examples given, the processor 18 sets up the mapping:

$$u = 425956 + 23974x + 01129y$$

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$$v = 74083 - 1129x + 23974y$$

$$x = -17.583 + 0.00004162u - 0.00000196v$$

$$y = -3.918 + 0.00000196u + 0.00004162v$$

### Setting Up the Mapping - Second Method

- 5 Alternatively, the mapping may be set up on the assumption that the nominal scale  $s_m$  of the map is correct, but that there may be some error in the coordinates  $(U_1, V_1)$ ,  $(U_2, V_2)$ ,  $(x_1, y_1)$ ,  $(x_2, y_2)$ . In this case, the corrected angle  $\Theta$  is still calculated in the manner described above. However, apart from that, the coordinates  $(U_1, V_1)$ ,  $(U_2, V_2)$  and the coordinates  $(x_1, y_1)$ ,  $(x_2, y_2)$  are averaged by the processor
- 10 18 to give the coordinates of midpoints  $(U_3, V_3)$ ,  $(x_3, y_3)$ , where:

$$U_3 = \frac{1}{2}(U_1 + U_2)$$

$$V_3 = \frac{1}{2}(V_1 + V_2)$$

$$x_3 = \frac{1}{2}(x_1 + x_2)$$

$$y_3 = \frac{1}{2}(y_1 + y_2)$$

- 15 In the example:

$$(U_3, V_3) = (435000, 085000)$$

$$(x_3, y_3) = (0.3550, 0.4721)$$

The map coordinates  $(U_0', V_0')$  corresponding to the origin  $(x, y) = (0, 0)$  of the active area 12 of the digitiser tablet 10 are then calculated by the processor 18 from :

20 
$$U_0' = U_3 - \{[x_3 \cdot \cos\Theta + y_3 \cdot \sin\Theta] \cdot s_m / s_d\}$$

$$V_0' = V_3 - \{[y_3 \cdot \cos\Theta - x_3 \cdot \sin\Theta] \cdot s_m / s_d\}$$

- In the example,  $(U_0', V_0')$  is calculated by the processor 18 as (425956, 074083), which happens to be the same as with the first example. Now that the values of  $(U_0', V_0')$ ,  $s_m$ ,  $s_d$  and  $\Theta$  have been determined by the processor 18, the mapping from the general
- 25 digitiser coordinate pair  $(x, y)$  to the general map coordinate pair  $(u, v)$  is given by:

$$u = U_0' + \{[x \cdot \cos\Theta + y \cdot \sin\Theta] \cdot s_m / s_d\}$$

$$v = V_0' + \{[y \cdot \cos\Theta - x \cdot \sin\Theta] \cdot s_m / s_d\}$$

and the inverse mapping from a general map coordinate pair  $(u, v)$  to a general digitiser coordinate pair  $(x, y)$  is given by:

30 
$$x = \{(u - U_0') \cdot \cos\Theta - (v - V_0') \cdot \sin\Theta\} \cdot s_d / s_m$$

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$$y = \{(v - V_0').\cos\Theta + (u - U_0').\sin\Theta\}.s_d/s_m$$

### Uses

Having set up the mappings between the two coordinate systems, they can be used to assist in providing many of the functions described in patent document

- 5 EP-A-0268628, such as:
- converting the current cursor position to map coordinates for display on the display 24 to provide information to the user;
  - converting the current cursor position to map coordinates for storage in the processor 18 as a waypoint;
  - 10 • converting the current cursor position to map coordinates in order to calculate the distance and/or bearing between that position and a stored waypoint;
  - converting a stored waypoint from map coordinates to digitiser coordinates and illuminating the indicators 28 accordingly so as to indicate to the user which way to move the cursor in order to place it over the waypoint; and
  - 15 • converting the current position of the GPS receiver 16 from map coordinates to digitiser coordinates and illuminating the indicators 28 accordingly so as the indicate to the user which way to move the cursor in order to place it over the current position.

### Summary of the Above Examples

- 20 In the examples described above, first the initial parameters  $s_m$ ,  $s_d$ ,  $g$ ,  $(u_c, v_c)$ ,  $(x_c, y_c)$  and  $\Theta$  are obtained or derived, from which an approximate mapping between the map and digitiser coordinate systems could be (or is) derived. Then, those initial parameters are corrected, modified or replaced by revised parameters on the basis of the digitiser coordinates of two grid intersections and an estimate (based on the initial
- 25 parameters) of the map coordinates of those two grid intersections to give the revised parameters  $S_m$ ,  $s_d$ ,  $\Theta$  and  $(U_0, V_0)$  or  $(U_0', V_0')$ . Then, the mappings  $(x, y) \leftrightarrow (u, v)$  are set up based on those revised parameters.

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### Modifications and Developments

It will be appreciated that many modifications and developments may be made to the examples of the invention described above. For example:-

I. Orientation of the Map. In steps "D" and "E" above, the cursor 14 is  
5 clicked on a position to the North, South, East or West of the current position. In order to permit the user to indicate easily and more accurately the orientation of the map, the facility may be provided for the user to click the cursor 14 on an arbitrary point on and towards the top of an arbitrary North-South running grid line, and then to click the cursor 14 on an arbitrary point on and towards the bottom of the same  
10 North-South running grid line. (Alternatively, of course, East-West running grid lines could be used.) The method of obtaining  $\theta$  may be simplified if it is a prerequisite that the map 30 is place on the digitiser tablet 10 generally one way up. Indeed, if it is prerequisite that the map 30 is laid generally one way up and generally square on the digitiser tablet 10, it may be possible to assume, for example, that  $\theta = 0$ .

15 II. Obtaining the Initial Parameters or Mapping. Other ways of obtaining the initial parameters or mapping may be employed. For example, the method described in patent document EP-A-0268628 may be employed and then revised in the manner described herein. As another example, if it is thought that the mapping provided by the method described above is not sufficiently accurate, the facility may be provided  
20 to enter one or more further grid intersection points, and the current mapping may then be updated on the basis of the last two entered grid intersections.

III. Other Map Coordinate Systems. The methods have been described above with reference to the OSGB map coordinate system, which has the advantage that, like the digitiser coordinate system, it is rectangular (and indeed square). The method  
25 may be used with other map coordinate systems, whether they be rectangular or not, including the latitude-and-longitude geographical coordinate system, which for the purposes of this specification is to be taken to be a "map" coordinate system.

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IV. Two or More Map Coordinate Systems. Indeed, it is to be noted that many GPS receivers provide position signals both in latitude-and-longitude and in another map coordinate system such as OSGB. Alternatively, the processor 18 may be programmed so that it can covert between coordinates in the map coordinate

5 system of the GPS receiver 16 and coordinates in some other map coordinate system(s). The cursor 14 may be arranged so that its display 24 can be toggled between the two (or more) map coordinate systems. It is also to be noted that many maps are marked with grid intersections for at least two different map coordinate systems. For example, the maps of the OSGB 1:50000 Landranger series mentioned

10 above are marked with complete OSGB primary grid lines at 10 km intervals, with complete OSGB secondary grid lines at 1 km intervals and also with latitude-and-longitude graticule intersections at 5 minute intervals. The methods described above may be modified so that, when the display 24 is set to display in one coordinate system (e.g. OSGB coordinates), it expects the cursor to be registered with a grid

15 intersection of that coordinate system (e.g. an OSGB grid intersection), and, when the display 24 is set to display in another coordinate system (e.g. latitude-and-longitude), it expects the cursor to be registered with a grid intersection of that other coordinate system (e.g. a latitude-and-longitude graticule intersection). In this case, two grid spacings may be stored by the apparatus, for example a grid spacing  $g = 10000$  m for

20 use when using OSGB coordinates, and a grid spacing  $g' = 5'$  for use when using latitude-and-longitude coordinates.

V. Revising the Initial Parameters using Only One Grid Intersection. Rather than producing the revised parameters on the basis of the digitiser coordinates of two grid intersections and an estimate (based on the initial parameters) of the map

25 coordinates of those grid intersections, it is possible to do so on the basis of the digitiser coordinates of only one grid intersection and an estimate (based on the initial parameters) of the map coordinates of that grid intersection. In this case, the initial mapping may be shifted (without scaling or rotation) to produce the revised mapping such that the chosen grid intersection becomes correctly mapped.

#### VI. Revising the Initial Parameters using More than Two Grid Intersections.

Even though the, for example, OSGB coordinate system is square, it may not appear as such on the map, for example because the map has stretched, shrunk or is wrinkled (resulting in a rectangular, rhombic or lozenged coordinate system) or because it is of low quality. Some other coordinate systems are not square. Also, the map may be in an atlas having a gap in the middle at the region of the spine of the atlas. In order to provide more accurate mappings between the digitiser coordinate system and the coordinate system actually appearing on the map, further grid intersections may be entered in the manner described above so that a mapping can be developed which is more complex than the simple translation, rotation and scaling employed in the detailed example given above. The more complex mapping could take account of, for example, different scales in different directions, the map grid lines being non-orthogonal, the map grid lines being non-parallel in one or both directions, and/or the map grid lines being curved. Indeed, with a mapping based on several entered intersections spread over the map, very little, if anything, needs to be known or assumed about the projection which was used in producing the map.

VII. The Grid Intersection Spacing "g". In the above example, the grid intersection spacing  $g$  is entered into (or previously stored in) the apparatus, and the example of  $g = 10000$  m was given for the map in question, corresponding to the spacing of the primary grid lines on the map, even though the map has finer grid lines marked on it with a finer grid spacing  $g_f$  of  $g_f = 1000$  m. The finer grid spacing  $g_f$  could have been used, but in that case the North, South, East or West direction needs to be more accurately entered in step "D" above in order to avoid the map coordinates of the first and second grid intersections being incorrectly guessed. For instance, in the specific example given in which the North direction was not indicated particularly accurately in step "D", if the finer grid spacing  $g_f = 1000$  had been used, then in step "L", the map coordinates of the second grid intersection would have been incorrectly estimated as  $(U_2, V_2) = (429000, 080000)$ , rather than  $(U_2, V_2) = (430000, 080000)$ . Indeed, if the facility is provided to update the mapping by entering further grid intersections, as described under modification "II" above, the coarser



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grid spacing  $g$  may be used for estimating the map coordinates of the first and second grid intersections, and the finer grid spacing  $g_f$  may be used for estimating the map coordinates of any subsequently entered grid intersections.

#### VIII. Entering Information about the Map.

In the example described above, the nominal scale  $s_m$  and the grid spacing  $g$  (and optionally  $g_f$ ) are entered by the user at some stage using the keypad 22. Alternatively, this information may be provided in machine readable form, such as in a barcode on the map, and the apparatus may have the facility to read it, for example with a barcode reader in the cursor 14. As another alternative, the apparatus may have the facility to display a list of common map types on the display 24, to store scale and grid spacing(s) for each map type, and for the user to select the appropriate map type, e.g. "OS Landranger 1:50000", whereupon the appropriate scale and grid spacing(s) are selected.

#### IX. Other Modifications and Developments.

As those skilled in the art will appreciate, the above system can be implemented by software running in conjunction with a programmable processor or can be implemented using dedicated hardware circuits which receive and process the information. The software for programming a general purpose processor can be provided on a recording medium, such as a floppy disc or CD ROM or can be downloaded from the internet on a carrier signal.

It should be remembered that the above description has been given purely by way of example, and that other modifications and developments may be made within the scope of the invention.

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CLAIMS:

1. A method of referencing a map with respect to a digitising apparatus, the map being marked with a set of grid points of a map coordinate system, the digitising apparatus having a digitiser coordinate system, and the method comprising the steps of:

determining parameters of an initial mapping between the map and digitiser coordinate systems;

storing or receiving information from which the spacing between the grid points can be determined;

receiving an indication from the user of a position which is at an arbitrary one of the grid points;

determining the digitiser coordinates of the indicated position;

determining, from the determined digitiser coordinates of the indicated position, the grid spacing information and the initial mapping parameters, the map coordinates of that one of the grid points which is at the indicated position; and

determining parameters of a revised mapping which takes account of the correlation between the determined digitiser coordinates and map coordinates of the indicated position.

2. A method as claimed in claim 1, wherein the revised mapping represents solely a translation of the initial mapping such that the determined digitiser coordinates and map coordinates of the indicated position are mapped onto each other by the revised mapping.

3. A method as claimed in claim 1 or 2, further including the steps of:

receiving an indication from the user of a second position which is at a second arbitrary one of the grid

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points;

determining the digitiser coordinates of the indicated second position; and

determining, from the determined digitiser  
5 coordinates of the indicated second position, the grid spacing information and the initial mapping parameters, the map coordinates of that one of the grid points which is at the indicated second position;

the revised mapping parameters also taking account  
10 of the correlation between the determined digitiser coordinates and map coordinates of the indicated second position.

4. A method as claimed in claim 3 when dependent  
15 directly on claim 1, wherein the revised mapping represents a translation, rotation and/or scaling of the initial mapping.

5. A method as claimed in claim 4, wherein the revised  
20 mapping is such that the digitiser coordinates and map coordinates of the indicated first-mentioned position are mapped onto each other, and the digitiser coordinates and map coordinates of the indicated second position are mapped onto each other, by the revised mapping.

6. A method as claimed in any of claims 3 to 5, further  
25 including the steps of:

receiving an indication from the user of a third  
position which is at a third arbitrary one of the grid  
30 points;

determining the digitiser coordinates of the indicated third position; and

determining, from the determined digitiser  
coordinates of the indicated third position, the grid  
35 spacing information and the initial mapping parameters,

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the map coordinates of that one of the grid points which is at the indicated third position;

the revised mapping parameters also taking account of the correlation between the determined digitiser coordinates and map coordinates of the indicated third position.

7. A method as claimed in any of claims 3 to 5, further including the steps of:

receiving an indication from the user of a third position which is at a third arbitrary one of the grid points;

determining the digitiser coordinates of the indicated third position;

determining, from the determined digitiser coordinates of the indicated third position, the grid spacing information and the initial or revised mapping parameters, the map coordinates of that one of the grid points which is at the indicated third position; and

determining parameters of a further revised mapping which takes account of the correlations between the determined digitiser coordinates and map coordinates of at least the indicated second and third positions.

8. A method as claimed in any preceding claim, wherein the step of determining the initial mapping parameters includes the steps of:

receiving an indication from the user of the current position of the user;

determining the digitiser coordinates of the indicated current position;

receiving an indication of the map coordinates of the current position of the user;

receiving an indication of the scale of the map; and

determining the initial mapping parameters from the

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map scale and the determined digitiser coordinates and received map coordinates of the current position of the user.

5 9. A method as claimed in claim 8, wherein the step of determining the initial mapping parameters also includes the step of receiving and taking into account an indication from the user of the relative orientation of the map and digitiser coordinate systems.

10 10. A method as claimed in claim 8 or 9, wherein map coordinates of the current position are obtained from a positioning system.

15 11. A method of referencing a map with respect to a digitising apparatus, substantially as described with reference to the drawings.

20 12. A digitising apparatus which is adapted to perform the method of any preceding claim.

13. A digitising apparatus for use with a map which is marked with a set of grid points of a map coordinate system, the digitising apparatus comprising:

25 a digitising surface (12) having a digitiser coordinate system and on which a map (30) can be laid;  
means (14) by which a user can indicate positions on the map on the digitiser surface;  
means (10, 14) for detecting the digitiser  
30 coordinates of the position indicated by the user with the indicating means;

first storing or receiving means (18) for storing parameters of an initial mapping between the map and digitiser coordinate systems;

35 second storing or receiving means (14, 18) for

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storing or receiving information from which the spacing between the grid points can be determined; and processing means (18) operable in a referencing mode to:

5           receive from the detecting means the digitiser coordinates of a position (36) which is indicated by the user with the indicating means and which is at an arbitrary one of the grid points;

10           determine, from the detected digitiser coordinates of the indicated position, the grid spacing information and the initial mapping parameters, the map coordinates of that one of the grid points which is at the indicated position; and

15           determine parameters of a revised mapping which takes account of the correlation between the detected digitiser coordinates of the indicated position and the determined map coordinates of the indicated position.

20   14. An apparatus according to claim 13, wherein said processing means is operable to generate a revised mapping which represents solely a translation of the initial mapping such that the determined digitiser coordinates and map coordinates of the indicated position.  
25   are mapped onto each other by the revised mapping.

15. An apparatus according to claim 13 or 14, wherein said processing means is operable, in said referencing mode, to:

30           receive an indication from the user of a second position which is at a second which is at a second arbitrary one of the grid points;

          determine the digitiser coordinates of the indicated second position; and

35           determine, from the determined digitiser coordinates

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of the indicated second position, the grid spacing information and the initial mapping parameters, the map coordinates of the grid point which is at the indicated second position; and

5        wherein the revised mapping parameters also take into account the correlation between the determined digitiser coordinates and map coordinates of the indicated second position.

10       16. An apparatus according to claim 15 when dependent upon claim 13, wherein said processing means is operable to generate a revised mapping which represents a translation, rotation and/or scaling of the initial mapping.

15       17. An apparatus according to claim 16, wherein said processing means is operable to generate a revised mapping which maps the digitiser coordinates and the map coordinates of the indicated first position onto each other and the digitiser coordinates and map coordinates of the indicated second position onto each other.

20       18. An apparatus according to any of claims 15 to 17, wherein said processing means is operable, in said  
25       referencing mode, to:

         receive an indication from the user of a third position which is at a third arbitrary one of the grid points;

         determine the digitiser coordinates of the indicated  
30       third position; and

         determine, from the determined digitiser coordinates of the indicated third position, the grid spacing information and the initial mapping parameters, the map coordinates of the grid point at the third position;

35       and wherein the revised mapping parameters also take

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into account the correlation between the determined digitiser coordinates and map coordinates of the indicated third position.

5 19. An apparatus according to any of claims 15 to 17, wherein said processing means is operable, in said referencing mode, to:

10 receive an indication from the user of a third position which is at a third arbitrary one of the grid points;

determine the digitiser coordinates of the indicated third position;

15 determine from the determined digitiser coordinates of the indicated third position, the grid spacing information and the initial or revised mapping parameters, the map coordinates of the grid point which is indicated by the third position; and

20 determine parameters of a further revised mapping which takes into account of the correlation between the determined digitiser coordinates and map coordinates of at least the indicated second and third positions.

25 20. An apparatus according to any of claims 13 to 19, wherein said processing means is operable, in said referencing mode, to determine the initial mapping parameters by:

receiving an indication from the user of the current position of the user;

30 determining the digitiser coordinates of the indicated current position;

receiving an indication of the map coordinates of the current position of the user;

35 receiving an indication of the scale of the map; and determining the initial mapping parameters from the map scale and the determined digitiser coordinates and



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received map coordinates of the current position of the user.

21. An apparatus according to claim 20, wherein said processing means is operable, during the determination of said initial mapping parameters, to receive and take into account an initial indication from the user of the relative orientation of the map and digitiser coordinate systems.

22. An apparatus according to claim 20 or 21, further comprising a positioning system for providing the map coordinates of the current position of the user.

23. A digitising apparatus for use with a map which is marked with a set of grid points of a map coordinate system, the digitising apparatus comprising:

a digitising surface having a digitiser coordinate system and on which a map can be laid;

a movable puck by which a user can indicate positions on the map on the digitising surface;

a detecting circuit for detecting the digitiser coordinates of the position indicated by the user with the puck;

a first memory or receiving circuit for storing or receiving parameters of an initial mapping between the map and digitiser coordinate systems;

a second memory or second receive circuit for storing or receiving information from which the spacing between the grid points can be determined; and

a processor operable in a referencing mode to:

receive from the detecting circuit the digitiser coordinates of a position which is indicated by the user with the puck and which is at an arbitrary one of the grid points;

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determine, from the detected digitiser coordinates of the indicated position, the grid spacing information and the initial mapping parameters, the map coordinates of that one of the grid points which is at the indicated position; and

determine parameters of a revised mapping which takes account of the correlation between the detected digitiser coordinates of the indicated position and the determined map coordinates of the indicated position.

24. A computer readable medium carrying instructions for configuring a programmable processor to become configured for use as the processing means of the digitising apparatus of any of claims 13 to 23.

25. A signal carrying instructions for configuring a programmable processing circuit as a processor for use in the digitising apparatus of any of claims 13 to 23.

26. A computer readable medium storing computer executable process steps for referencing a map with respect to a digitising apparatus, the process steps comprising:

steps for determining an initial mapping between the map and digitiser coordinate systems;

steps for storing or receiving information from which the spacing between grid points of the map coordinate system can be determined;

steps for receiving an indication from the user of a position which is at an arbitrary one of the grid points;

steps for determining the digitiser coordinates of the indicated position;

steps for determining, from the determined digitiser

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coordinates of the indicated position, the grid spacing information and the initial mapping parameters, the map coordinates of that one of the grid points which is at the indicated position; and

5       steps for determining parameters of a revised mapping which take account of the correlation between the determined digitiser coordinates and map coordinates of the indicated position.

10    27. Computer executable process steps for referencing a map with respect to a digitising apparatus, the process steps comprising:

      steps for determining an initial mapping between the map and digitiser coordinate systems;

15       steps for storing or receiving information from which the spacing between grid points of the map coordinate system can be determined;

      steps for receiving an indication from the user of a position which is at an arbitrary one of the grid  
20   points;

      steps for determining the digitiser coordinates of the indicated position;

      steps for determining, from the determined digitiser coordinates of the indicated position, the grid spacing  
25   information and the initial mapping parameters, the map coordinates of that one of the grid points which is at the indicated position; and

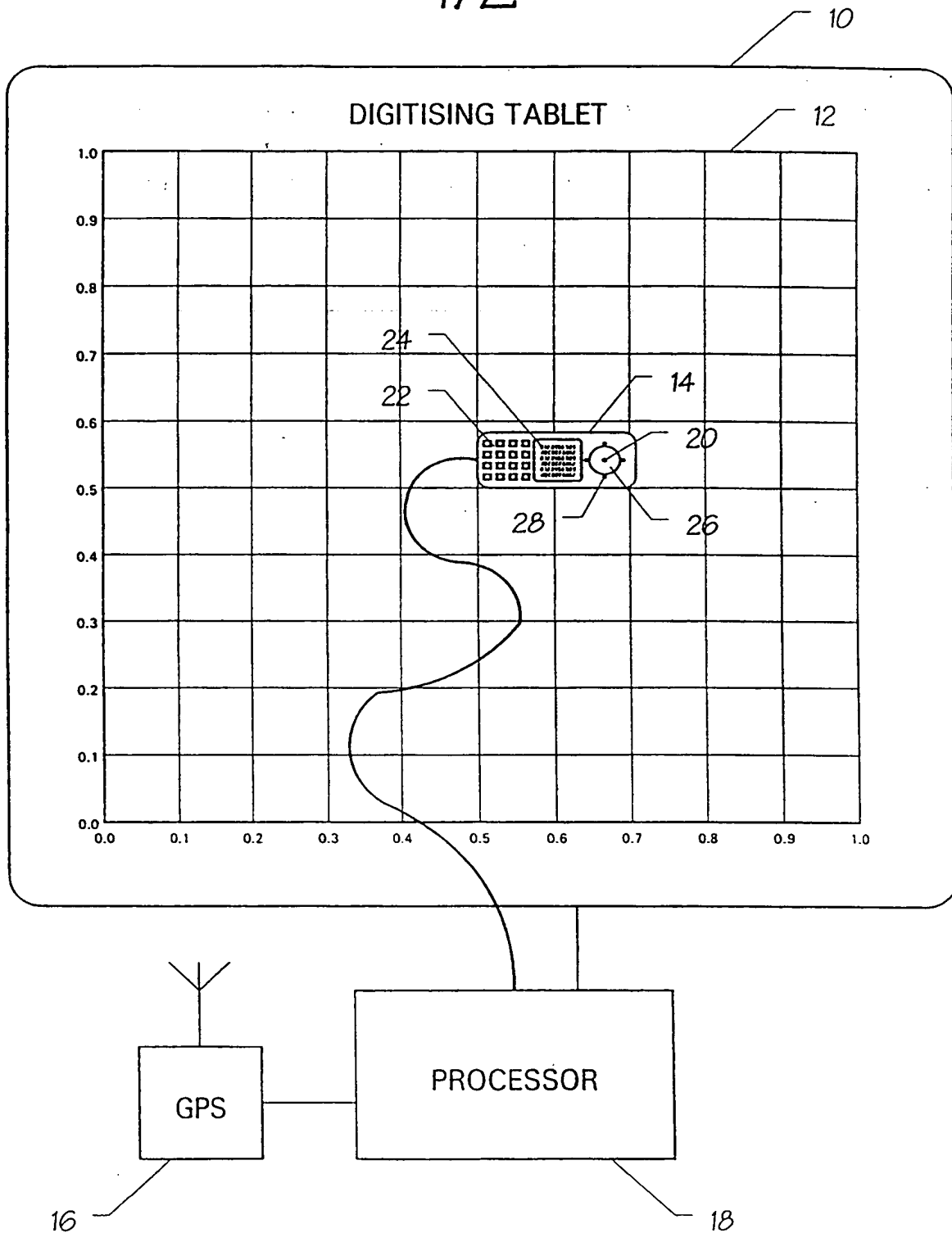
      steps for determining parameters of a revised mapping which take account of the correlation between the  
30   determined digitiser coordinates and map coordinates of the indicated position.

28. A digitising apparatus, substantially as described with reference to the drawings.

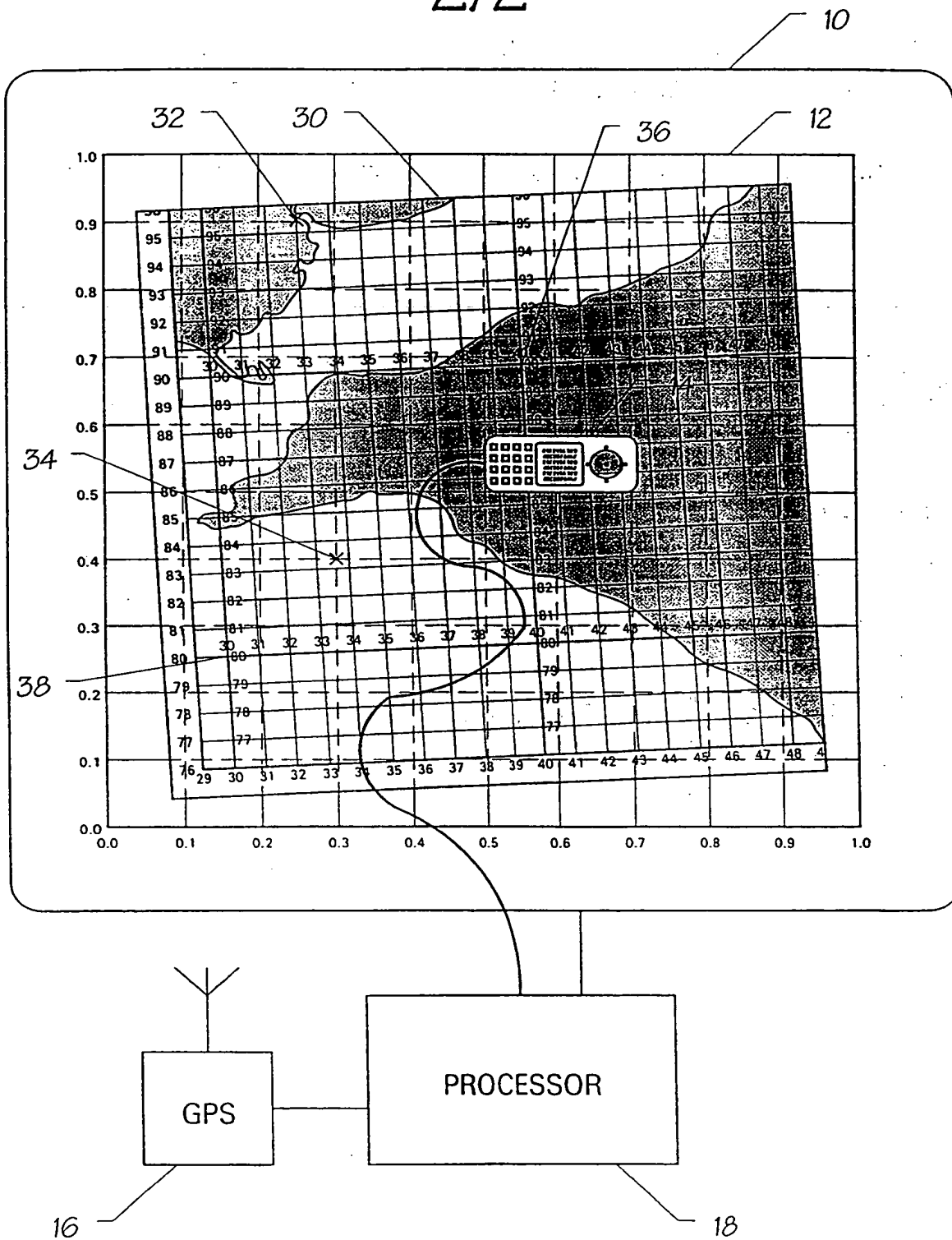
- 26 -

29. A navigational aid comprising a digitising apparatus according to any of claims 13 to 23 and a global positioning system for identifying a current position of a user on a map referenced with the digitising apparatus.

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# INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 99/01275

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 6 G01C21/22 G09B29/10

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 6 G01C G09B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, X	US 5 751 276 A (SHIH YUNG-HO) 12 May 1998 (1998-05-12) the whole document ---	1-8, 13-27
Y	WO 97 19322 A (QUDOS SA ; AGNEW HUGH JOHN (AU); PARFITT GWYN DAVID WALTER (HK)) 29 May 1997 (1997-05-29) page 12, line 36 - page 13, line 25; claims 1,10,11; figure 6 ---	1,3,5,8, 10,13, 23,26,27
Y	WO 95 01551 A (GEOGRAFIX LTD ; GOODWIN DAVID (GB)) 12 January 1995 (1995-01-12) cited in the application page 5, line 18 - page 8, line 28; claims 1-10,13; figures 1-4 ---	1,3,5,8, 10,13, 23,26,27
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Date of the actual completion of the international search

12 August 1999

Date of mailing of the international search report

19/08/1999

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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	EP 0 597 500 A (DAINIPPON PRINTING CO LTD) 18 May 1994 (1994-05-18) the whole document	1



# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 99/01275

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